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Research article

The equatorial rainforest of Central Africa between economic needs and sustainability requirements

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ABSTRACT

This article sets out to investigate the role played by the rainforest of Central Africa in providing environmental goods and services, regulating and stabilizing the global climate as well as participating in socio-economic development of the riparian countries. This complex role offers a double status, almost confrontational, to this rainforest: it stands as an economic resource and as a major global climate regulator. Hence, there is an urgent need to question certain aspects such as climate trends in this strategic region and the use of local forest resources for economic purpose in order to suggest ecological attitudes to be adopted by policymakers, stakeholders, forest professionals and users for a sustainable development. It is shown that: 1) this rainforest constitutes an economic resource and plays a major socio-cultural role in addition to its global climate regulatory role, 2) an overexploitation of the forest resources for economic purposes exposes the forest to an increased deterioration which can change the ecological and socio-economic balance, or destroy this forest, and by so doing, alter its global climate control power, 3) the climate of the region is experiencing serious variability. Thus, solutions that can satisfy socio-economic needs and give room for sustainable development are proposed.

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1. Introduction

Almost all policymakers, stakeholders, researchers, scientists and non-governmental organizations are unanimous that climate variability is one of the Millennium challenges (UN, 2015). The equatorial rainforest of Central Africa is also falling prey to this phenomenon. Arétouyap et al., 2014 showed climate variability has a toll on water resources in Central Africa. Conway (2009) investigated the climate variability in Africa in terms of impacts and adaptation. Hulme et al. (2005) worked on the warming rate in Africa. IPCC (2007; 2014) recapped the situation of climate variability in the world including the region under study. Justice et al. (2001) analysed the carbon budget in Central Africa and related climate variability. Almost all those investigations conclude that, within the rainforest of Central Africa, temperature is increasing while rainfall has a downward trend. But, no interaction between sustainability requirements, depending on this climate variability, and economic needs, depending on these forest resources, has not yet been investigated.

Such climate variability in Central Africa requires more international attention and interest because of the “regulator role” it plays in the global climate system. Indeed, through photosynthesis, trees produce sugars from carbon dioxide, light and water, and some of them are stored in the form of wood. Hence, rainforests act as atmospheric carbon sinks, helping to limit the impact of global warming. In fact, though primary forest cover sequesters just little atmospheric carbon, it does store a great deal. Hence, deforestation may lead to the release of an important amount of carbon. Consequently, when a tree is cut down, it releases a lot of carbon in the atmosphere. This may lead to the formation of carbon oxides and many other greenhouse gases, responsible for global warming. The equatorial rainforest of Central Africa provides a good range of economic and cultural advantages to many major industries and companies worldwide at the time. In rural areas, more than 30 million people largely rely on this natural resource for their livelihood. The uses they make of the resource have been classified into three major categories by Dkamela et al. (2013): supply service that

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includes wood, vegetables and medicinal plants; natural regulation service for climate and water control; and cultural service that refers to spiritual and cultural identity.

It is observed that the equatorial rainforest of Central Africa plays two major roles that are almost conflicting and ambivalent: regulating global climate and satisfying economic needs. The main objective of this article is to show that Central Africa is witnessing climate change, bring to limelight the conflicting roles of the local rainforest listed above and then propose solution to this dilemma.

2. Conceptual framework

2.1. The rainforest of Central Africa as a "global climate regulator"

The equatorial region of Central Africa is a real pool of plant and animal species. This region is characterized by the immense virgin forest density expanded through five countries: Cameroon, Central African Republic, Equatorial Guinea, Gabon and Democratic Republic of Congo (Fig. 1). As such, it has a great ability to regulate global climate through photosynthesis as mentioned above. The rainforest capacity to trap atmospheric carbon makes it an essential means of global warming mitigation.

Conversely, deforestation and forest degradation would lead to the release of huge amounts of greenhouse gases into the atmosphere. Indeed, during photosynthesis, trees absorb carbon dioxide molecules and transform them into carbon stored in the biome. Biomes are huge carbon sinks. According to Dkamela et al. (2013), deforestation is responsible for 15–20% of greenhouse gas emissions. Deforestation has to do with felling trees and using land for other purposes such as agriculture.

Forests play an important role on the environment patterns. This includes purifying air, preserving watersheds, improving water quality and quantity, stabilizing soil, providing people with natural resources such as timber products and medicinal plants, and helping to protect the planet from climate change by absorbing carbon dioxide, the main greenhouse gas (https//www.assets.penda.org/downloads/intro_factsheet_27nov07_lr.pdf). Increasing concentrations of carbon dioxide are driving rise in air temperature.

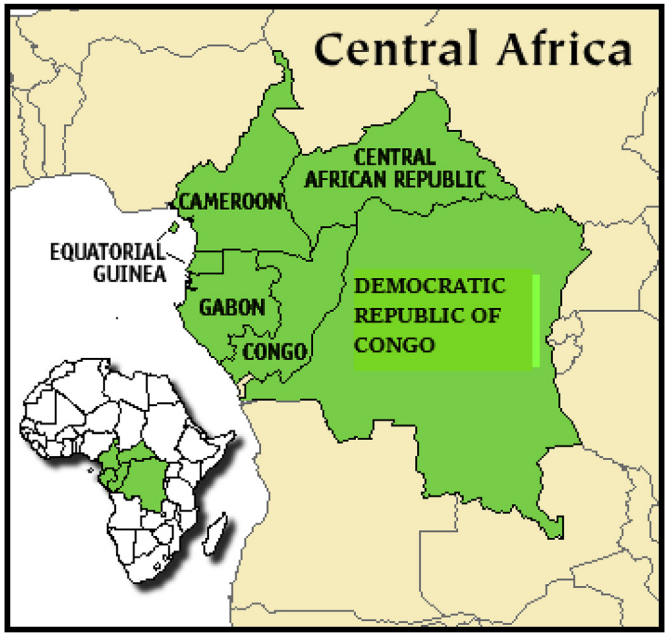

Fig. 1. Study area.

Hence, forests play a critical role in protecting the planet from climate change and regulating climate patterns. In fact, tree trunks, branches and roots absorb and store carbon dioxide, providing a natural reservoir for this greenhouse gas. According to a World Wide Fund report, Earth's vegetation and soils currently contain the equivalent of approximately 7.5×10^{12} kg of carbon oxide (FAO, 2011; Moutinho and Schwartzman, 2005). As a result, when forests are destroyed, they release large quantities of carbon oxide, and become a significant source of carbon oxide and other greenhouse gases emissions. Those emissions contribute widely to climate change (Lawrence and Vandecar, 2015). Indeed, the contribution of deforestation to carbon emissions is estimated at ~19% of global emissions. This amount is greater than those emissions produced by the whole of the global transport sector. Yet, deforestation is continuing at an alarming rate. UN Food and Agriculture Organization (FAO, 2006) indicates that the rate of natural tropical forest loss is about 13 million hectares each year.

2.2. Related economic role of the rainforest and livelihood of inhabitants

The equatorial rainforest of Central Africa constitutes both the natural shelter and subsistence conditions for millions of people. More than 40 million of them depend directly on the forest resources (FAO, 2006; FAO et al., 2015). This symbolizes the socio-economic role played by this ecosystem. And these socio-economic needs are increasing by day. For example, bioenergy, made up of wood for 95%, is becoming a major source of global energy supply. While its traditional use still prevails in developing countries, developed countries have witnessed the expansion of new applications. Cushion et al. (2010) demonstrated that by 2030, almost 2.7 billion of people around the world will be using fire wood for cooking. Bioenergy is the main source of energy in Africa and accounts for 65% of total primary energy source. This energy source is also used elsewhere in the world. Kolovos et al. (2011) highlight specific woodfuel types that are more cultivated in the Northern Greece. Taking into consideration such factors as 'high heating values', densities, annual total production, and annual proportional allocation of the available woodfuels, those researchers evaluated the adequate environmental, economic and socio-economic conditions of relevant projects. Their findings seem to set the scene for a solution to the requirement of environment-friendly and economical fuels to the everyday energy-consumption imposed by the European Legislation on human activities (Chalikias et al., 2010).

Okali (2011) highlighted that the socio-economic conditions and the production system of local population are strongly linked to the tropical rainforest. Indeed, he stated that the rainforest supplies residents with wood for furniture and building, firewood, medicine and drugs, foodstuffs, stock for drought periods. Furthermore, the transformation and exploitation of some forest resources like wood, fruits, nuts and gums generate important revenue for the region. The exportation of wooden products contributes for more than 60% to the gross domestic product of the local countries (FAO, 2006).

2.3. Sustainability requirements

A significant reduction of the phenomenon of climate variability requires a sustainable forest management. This would produce long-term goods and services while maintaining at an acceptable level environmental benefits from forests and without diminishing the upcoming integrity of those forests. It is an approach capable of optimizing carbon storage while providing economic and environmental benefits (Dkamela et al., 2013). It is imperative to

strengthen civil and legal forest legislation. That is to say popularize the standards and Forest Certification by educating and directing citizens to solely consume forest products on regular, legal and sustainable operations' basis; severely punish any nonconforming operator; integrate incompressible needs of different social strata in the exploitation of the forest through an integrated management plan for community forests.

2.4. Conflicting interaction

Forest trees are of a paramount importance for carbon sink, absorption and transpiration of water useful for rainfall synthesis, conservation of soil fertility and shelter for millions of plant and animal species. Although it has been demonstrated that rainforest constitutes important component for global climate regulation, biodiversity conservation and sustainability setting, this ecosystem remains very coveted for economic ends as shown in previous Subsection 2.2. This contradictory and conflicting role is very delicate and alters, *a priori*, the sustainability requirements of the rainforest. In fact, the primary and natural impact of economic activity on the forest is deforestation, due among others to the overexploitation, irrational exploitation, agriculture, intensive collection of firewood and population growth (Muoghalu, 2012). Nowadays, trees are more and more exploited for woodfuel purpose. This phenomenon is a common practice in many countries through the world. Kyriakopoulos (2010) explained that woodfuels are of paramount importance for livelihood in rural areas, and consequently strengthen the local economies. This source stands as an alternative energy source in the conventional coal-based energy network.

Hence, the management policy of the equatorial rainforest must change deeply. Policymakers and forest users have to integrate the notion of sustainability in their life-style. Strict measures should be taken in order to mitigate the damage. This includes among others the spread/vulgarization of practices that have a low impact on forest, the valorization of new plant species, the protection of the existing primitive forest, and new tree plantings. Stakeholders and non-governmental organizations should also fund the development of the green economy and renewable energy, and promote the energy efficiency. The following Section investigates the current warming trend in the region, using data collected from the local meteorological stations.

3. Method and materials used to investigate warming trend in the region

Taking into consideration the importance of air temperature and the availability of a long-term temperature record in the Central Africa region, an attempt has been made to understand the warming trend in the last half century in this region. The annual and seasonal temperature variations have also been analysed in order to understand the trend.

3.1. Current context

The literature already mentioned the high sensitivity of the Central Africa region to the phenomenon of global change. However, climate forecasts are neither enough nor accurate (Muoghalu, 2012). During the closing century, the temperature increased by 0.7 °C in average (IPCC, 1998), while rainfall is witnessing a drop (Arétouyap et al., 2014). The rainforest of Central Africa is therefore one of the most sensitive ecosystems to such climate variability (IPCC, 2007). The question is all the more worrying in the sense that this forest also influences climate variability in two ways. Indeed, its presence and development constitute a carbon sink while its destruction is a source of greenhouse gases emission. Thus, it is very necessary to conduct a rational analysis of existing climate data.

3.2. Data analysed

Weather data are provided by national weather stations and parks, regional and international partner agencies like the Agency for the Safety of Air Navigation in Africa and Madagascar (ASECNA) and the World Meteorological Organization (WMO), and the time span 1960 to 2010 is considered for analysis (our study period). Functioning periods common to all stations were chosen. The latter criterion enables to carry out a regional interpretation of trend detection tests. All data were checked in order to find out if there is any breakdown resulting from a change in meteorological conditions. This investigation is guided by Buishand's break test, Petitt's break test and Hubert's segmentation test. All these tests confirmed the consistence and the compatibility of stations used.

3.3. Methodology

In order to efficiently perform seasonal analysis, the dataset has been divided into four periods. Period 1: December–February, period 2: March–May, period 3: June–September, and period 4: October–November. In fact, the local meteorology is characterized by four main alternative seasons: two rainy seasons matching with period 2 and period 4, and two dry seasons matching with period 1 and period 3. It should be noted that seasonal and annual data derive from monthly data. Furthermore, trends are deducted using the Mann-Kendall test (Kendall, 1975; Mann, 1945). Outliers were checked in order to improve the quality of parametric tests (Darshana and Pandey, 2013; Eischeid et al., 1995; Feng et al., 2004; Grant and Leavenworth, 1972; Peterson et al., 1998; Xu and Ignatov, 2014).

In general, correlation within a data series has serious impacts on the implementation of the Mann-Kendall test. This can result in an overestimation of the significance of a trend in the case of positive correlation or in an underestimation if data are negatively correlated. To reduce such negative impacts, Yue et al. (2002) recommended the trend-free Pre-Whitening (TFPW)-MK procedure. The autocorrelation test primarily conducted demonstrates the non significance of the serial correlation coefficients at lag 1. For this, all statistical tests described in the above paragraph have not been applied (Hann, 2002; Luo et al., 2007).

3.3.1. Autocorrelation test of independence

This important test conducted using values of the correlation coefficients calculated from all pairs of data points separated by k timeperiods (where k is the lag time) is estimated using equation (1) at the 5% significance level (Wallis and O'Connell, 1972).

$$r_1 = \frac{\sum(x_t - \overline{x})(x_{t+1} - \overline{x})}{\sum (x_t - \overline{x})^2} \quad (1)$$

where $\overline{x} = \sum x_t$ is the overall mean of N sample sizes.

The first-order autocorrelation coefficient r_1 can be tested against the null hypothesis using Anderson's limit for the two-tailed test (equations (2) and (3)).

$$r_1(95\%) = \frac{-1 \pm 1.96\sqrt{N-2}}{N-1} \quad (2)$$

$$r_1(90\%) = \frac{-1 \pm 1.645\sqrt{N-2}}{N-1} \quad (3)$$

3.3.2. Mann-Kendall test

The main benefit of using this important test, widely used by many researches in meteorological and data analysis (Darshana and Pandey, 2013; Gocic and Trajkovic, 2013; Goossens and Berger, 1986; Kadioglu, 1997; Mitchel et al., 1966; Tayanc and Toros, 1997), is that it can even be applied to the data series, which is not normally distributed (Hamed, 2009). It is based on the test statics S defined in equation (4).

$$S = \sum_{j=1}^{n-1} \sum_{j=i+1}^{n} sgn(x_j - x_i) \quad (4)$$

$$\text{And } sgn(x_j - x_i) = \begin{cases} 1 \text{ if } (x_j - x_i) > 0 \\ 0 \text{ if } (x_j - x_i) = 0 \\ -1 \text{ if } (x_j - x_i) < 0 \end{cases} \quad (5)$$

where $x_1, x_2, \ldots, x_n$ represent 'n' data points where x_j represents the data point at time j.

An increasing trend is interpreted as a result of a very high positive value of S while a decreasing trend results from a very low negative value.

Chaouche et al. established that when $n \geq 10$, the statistic S is approximately normally distributed with the mean $E(S) = 0$, and its variance is given by equation (6).

$$Var\ (x_j - x_i) = n(n-1)(2n+5)\sum_{i=1}^{m} t_i(t_i-1)(2t_i+5) \quad (6)$$

where n is the number of data points, m is the number of tied groups (a tied group is a set of sample data having the same value), and t_i is the number of data points in the *ith* group.

3.3.3. Spearman rank correlation (SRC) test

This test is performed through coefficient r given by equation (7).

$$r = 1 - 6\left\{\frac{\sum_{i=1}^{n} di^2}{n(n^2-1)}\right\} \quad (7)$$

where i represents the chronological order and n the total number of data points in the series. $d_i = RX_i - RY_i$, where RX_i is the rank of variable X_i, which is the chronological order of the observations. The series of observations Y_i is transformed into its equivalent rank RY_i by assessing the chronological order in the ranked series. For the ties, an average rank will be considered. The test statistic t used for this purpose is given by equation (8).

$$t = r\sqrt{\frac{(n-2)}{(1-r)^2}} \quad (8)$$

The null hypothesis implies that no trend will be rejected if $t_{v,\alpha/2} < t < t_{v,1-\alpha/2}$, where the test statistic t follows a Student's t distribution with degrees of freedom $v = n - 2$ and significance level α.

3.3.4. Sen's slope (SS)

This method is used to compute the magnitude of the slope (equation (9)).

$$b = Median\left[\frac{Y_i - Y_j}{i-j}\right] \text{ for all j } < 1 \quad (9)$$

where Y_i and Y_j are data at time points i and j, respectively. If the total number of data points in the series is n, then there will be $n(n-1)/2$ slope estimates. Positive and negative signs of test statistics indicate increasing trend and decreasing trend, respectively.

3.3.5. Sequential Mann-Kendall's test (SQMT)

This test helps compute the beginning and the duration of changes over the entire study period (Modarres and Sarhadi, 2009; Sneyers, 1990). Progressive and retrograde analyses of the Mann-Kendall test produce sequential values u(t) ant u'(t), respectively. To achieve this, we first need to find out the number fo times when $X_j > X_i$, where X_i and X_j are the sequential values in a series, X_j (j = 1, …. n) are compared with X_i (i = 1, …, j). This number is noted n_j. The SQMT test is conducted using equation (10).

$$t_i = \sum_{i}^{j} n_j \quad (10)$$

The mean and variance of the test statistic t_j are given in equations (11) and (12) respectively.

$$E(t) = \frac{n(n-1)}{4} \quad (11)$$

$$Var(t_j) = \frac{j(j-1)(2j+5)}{72} \quad (12)$$

After that, the progressive sequential value u (t_j) is calculated using 13.

$$u\ (t_j) = \frac{t_j - E(t)}{\sqrt{Var(t_j)}} \quad (13)$$

In the same way, $u'(t_j)$ is calculated starting from the end of the series.

4. Results and discussion

4.1. Preliminary analysis

Temperature data collected from the 4 localities (Banyo, Meiganga, Ngaoundere and Tibati) from 1960 to 2010 were individually analysed. Different statistical factors such as mean, standard deviation, skewness, and kurtosis of the annual mean temperature have been computed.

In Banyo, the annual minimum temperature shows a variation of 2.9 °C, while the annual maximum and the annual mean temperature reveal a variation of 4.7 °C and 2.5 °C respectively. In Meiganga, the annual minimum temperature indicates a variation of 8.5 °C, whereas the annual maximum temperature shows a variation of 3.7 °C and 2.7 °C for the annual mean temperature. The variation of the annual minimum temperature in Ngaoundere shows 3.5 °C, 2.6 °C and 3.6 °C for the annual maximum and the annual mean temperature respectively. In Tibati, the annual minimum temperature reveals a variation of 9.6 °C; 3.7 °C and 2.6 °C for the annual maximum and the annual mean temperature variation respectively. These figures represent the difference between the yearly average max and min values of each category. These magnitudes are summarized in Table 1.

The skewness is positive for 80% of the time in the case of maximum temperatures, and for 56% and 64% of the time for

Table 1
Magnitude of variation of maximum, minimum and mean temperature over the study period in the region.

	Minimum (°C)	Maximum (°C)	Mean (°C)
Banyo	2.9	4.7	2.5
Meiganga	8.5	3.7	2.7
Ngaoundere	3.5	2.6	3.6
Tibati	9.6	3.7	2.6

minimum and mean temperatures, respectively. Kurtosis ranges from −1.70 to −1.21 °C, from −1.62 to −0.87 °C and from −1.58 to −1.04 °C, respectively for maximum, minimum, and mean temperatures.

4.2. Analysis of temperature anomalies

Temperature anomalies can be defined as the deviation from the normal trend. In the present study, these anomalies have been analysed for a better understanding of the variations in the maximum, minimum and mean temperatures from 1960 to 2010 time span. The positive anomaly was noticed in the for maximum, minimum and mean temperatures in Banyo and in Tibati. The same trend cuts across the maximum and mean temperatures in Meiganga, while the minimum temperature in this locality is almost constant. Besides, a downward trend is observed in the region for maximum and mean temperatures while the minimum temperature is constant. This change in trends is illustrated in Figs. 2–5, submitted as Supplementary Material. A noticeable warming trend has been observed for the maximum temperature from all stations except in Tibati where one could nevertheless see a peak of 28.5 °C in 1973. The annual minimum temperature equally indicates an upward trend except in Meiganga and in Tibati where it is constant. Tibati is the unique locality that shows a downward trend for the mean temperature. Changes observed may enhance deforestation and drought that will adversely impact freshwater and other forest resources available in the region, and the global greenhouse gases spread in the world. Obviously, the dry season has the downward trend with negative values in Meiganga and Tibati.

4.3. Four-yearly variations of annual and seasonal temperature

The four-yearly temperature variation is analysed in this investigation in order to detect any potential fluctuation or irregularity of the warming rate. Results are presented in Table 2 where they are compared with data for the entire period (1970–2010). In Banyo, the variation is positive for annual and rainy season temperatures except during 1971–1980 and 1996–2000, negative for the dry season except during 1981–1985 and 2000–2010. In Meiganga, the variation is positive for the rainy season temperature. The tendency is the same for the annual temperature except during 1971–1975 and for the dry season except during 1971–7975, 1981–1985 and 2005–2009. In Ngaoundere, the variation is positive for the dry season. The tendency is the same for the annual temperature except during 1981–1985 and for the rainy season except during 1971–7975, 1981–1985 and 2005–2009. In Tibati, 1981–1985 and 1996–2000 periods reveal negative variation for annual and rainy season temperatures while the period 2005–2009 shows negative variation for annual and dry season temperatures.

From the general perspective, anomaly for annual temperature in the region rages from −0.34 °C to 2.07 °C. For the dry season, this anomaly ranges from −1.68 °C to 3.11 °C. And for the rainy season, the anomaly ranges between −0.59 °C (in Tibati) and 2.29 °C (in Ngaoundere).

4.4. Results of Mann-Kendall (MK), spearman rank correlation (SRC), Sen's slope (SS) and sequential Mann-Kendall (SQMK) tests and linear regression test

Results of all these tests for T_{max}, T_{min}, and T_{mean}, presented in Table 1 and illustrated in Figs. 2–5 (Supplementary Material) reveal a significant increase in the trend of those parameters in almost all months.

In the MK test, the analysis of the maximum temperature showed a significant warming trend for all the months, except January–March and October–December periods in Tibati, from 1960 to 2010. Using the linear regression test, the highest monthly rate of change in Banyo is 3.00 °C (December), 2.75 °C in Meiganga (April), 3.85 °C in Ngaoundere (September), and 1.00 °C in Tibati (August). The rainy season exhibits an upward trend in all stations while dry season shows a slight drop in temperature change in Meiganga and Tibati.

4.5. Socio-economic and environmental impacts

An intense exploitation of the rainforest for economic purpose leads to various environmental consequences with serious socio-economic impacts. Although positive economic impacts regarding some domains as gross domestic product, trade balance and gross national income exist, this Subsection mainly discloses socio-economic and landscape aesthetic impacts of deforestation (Table 3).

Undoubtedly, deforestation increases the gross domestic product of concerned countries, but it also seriously damages the quality of life of residents. When native populations lose their land, their agriculture yield decreases, with food insecurity and household income drop as main results. Their natural sheltering condition is also altered. Deforestation also leads to carbon emissions and accelerates the phenomenon of climate variability. Yet, a combination of temperature rise and rainfall drop affects quantitatively and

Table 2
Four-year variations of mean annual, dry and rainy season's temperatures (°C) over the study area.

Interval	Banyo			Meiganga			Ngaoundere			Tibati		
	Annual (°C)	Dry (°C)	Rainy (°C)	Annual (°C)	Dry (°C)	Rainy (°C)	Annual (°C)	Dry (°C)	Rainy (°C)	Annual (°C)	Dry (°C)	Rainy (°C)
71–75	−0.180	−0.130	−0.205	−0.077	−0.560	0.175	0.003	0.110	−0.050	0.323	0.190	0.390
76–80	−0.053	−0.050	−0.055	1.000	0.255	1.372	1.127	0.730	1.325	0.800	0.740	0.830
81–85	0.090	0.095	0.088	0.000	−0.775	0.388	−0.267	0.095	−0.448	−0.427	0.340	−0.810
8–90	0.033	−0.140	0.120	0.345	0.130	0.452	0.177	0.755	−0.112	0.084	0.280	0.010
91–95	0.099	−0.196	0.247	0.067	0.020	0.090	0.290	0.165	0.352	0.348	0.110	0.482
96–00	−0.237	−0.178	−0.267	0.093	0.050	0.115	−0.030	0.070	−0.080	−0.363	0.090	−0.590
00–04	0.875	1.318	0.607	2.010	3.105	1.515	0.836	1.813	0.306	0.370	1.086	0.012
05–09	1.274	1.201	1.302	0.693	−0.585	1.341	2.072	1.628	2.289	−0.350	−1.683	0.312

Table 3
Environmental and socio-economic impacts of deforestation.

Environmental or Social impacts	Potential indicator or manifestation
Food security	• Surge in food prices • Malnutrition • Risk of hunger • Riot
Land access	• Access to land • Land prices
Household income	• Drop of rural inhabitants' income • Poverty
Health	• Exposure to dangerous radiation • Extinction of plant species used for local medication • Rise of new diseases
Quality of life	• Degradation of life quality due to poverty, poor-health and income drop
Water quantity and quality	• Water scarcity • Consumptive water use • High need of water for agriculture
Soil quality	• Soil carbon content • Erosion • Soil fertility
Carbon emissions	• Change in greenhouse gas emissions • Atmospheric pollution • High concentration of carbon oxide
Biodiversity	• Forest shattering • Habitat loss • Biodiversity loss
Ecosystem services	• Change in ecosystem service provisioning • Extinction of some plant and animal species
Landscape	• Destructuralization • Ugliness

qualitatively local surface and groundwater. Medicinal plants are destroyed and health condition deteriorated. Soil quality, biodiversity and ecosystem services are also seriously damaged. Landscape is also seriously threatened by the phenomenon of deforestation (Papadimitriou, 2010, 2012).

From an environmental viewpoint, the rainforest plays a key role in the biochemical cycling of nutrients. Indeed, Turner (2010) stated that nutrients from organic compounds (i.e. from wood, leaves and other forest products) provide important information on biogeochemical cycles in tropical soils. Yet, physico-chemical properties of a soil seriously affect the soil productivity with hunger and economic slump as major potential consequences. This is why in order to advise farmers on the economic practices to engage in, Tale and Ingole (2015) reviewed the roles of several physico-chemical properties (electric conductivity, moisture, texture, organic matter, temperature, etc.) on soil quality.

Yet, many initiatives have already been taken in order to reconcile both roles of “economic provider” and “global regulator” played by the rainforest. For example, various protected areas have been created. In fact, millions of indigenous people are closely dependent on forest resources since they have been considering those resources as their traditional and natural rights (Amrose, 2003). Therefore, their opinion and requirements should be taken into account when creating a protected area (Nkongmeneck et al., 2013). Wells and McSchane (2004) demonstrated that local participation is crucial for the sustainability of protected areas in developing countries. Innovative approaches such as the involvement of the private sector is being experienced (Wasseige et al., 2009). Nkongmeneck et al. (2013) proposed a “bottom-up” instead a “top-down” approach, which may deeply involve local people with their culture and traditional habits, when designing a conservation project. And according to Edwards and White (2001), this collaboration may be observed during designing, implementation, monitoring and evaluation steps. For this reason, all donors including governments, stakeholders, non-government organizations and municipalities should increase their respective budgets in order to train local residents for a better implication.

5. Conclusion and perspectives

The present investigation reveals that the rainforest of Central Africa plays a double role that is almost contradictory: the role of a major socio-economic resource and that of a key global climate regulator. The role of economic resource is likely to alter irreversibly its capacity to regulate climate if no appropriate measures are taken in order to limit the damage. And this catastrophic situation may be accentuated by the upward trend in temperature that is already observed nowadays in the region. Fortunately, policy-makers and loggers in the region have put in place clear cap policies (Bitondo, 2012) in order to curb the risk. At the sub-regional level, the Central Africa Forests Commission (CAFCOM) was established during the Yaounde Summit, held in March 1999. This Commission is a political and legal framework that embodies the commitment of Heads of State of Angola, Burundi, Cameroon, Chad, Congo, DR Congo, Equatorial Guinea, Gabon, Rwanda, and Sao Tome and Principe to work diligently for the preservation of the equatorial rainforest of Central Africa. This Commission also provided for the right of coastal peoples to enjoy the resources from these forests (Gilpin, 2001; FAO, 2011; Bitondo, 2012; FAO et al., 2015). Other initiatives are taken at national levels. These are initiatives which together are intended to guide the forest sector's contribution to socio-economic development and to promote conservation, protection and regeneration of the forest. These initiatives would thus ensure the maintenance of biodiversity and ecological, social and economic functions inherent to forests.

Despite these initiatives, worrying signs of climate variability are visible in the region. The analysis indicated that there is an overall warming trend in the region except in Tibati. For maximum temperature, an increasing per decade of 0.24 °C in Banyo, 0.36 °C in Meiganga, 0.5 °C in Ngaoundere, was observed, and a decreasing variation of −0.1 °C per decade in Tibati. For minimal temperature, this study reveals a variation per decade of +0.47 °C in Banyo, -

0.10 °C per decade in Meiganga, + 0.50 °C in Ngaoundere and +0.09 °C in Tibati. Mean temperature shows a variation per decade of +0.36 °C in Banyo, 0.20 °C in Meiganga, +0.59 °C in Ngaoundere and - 0.10 °C in Tibati.

The equatorial rainforest of Central Africa is bound to satisfy the needs for wood products of the local populations, and in industrialized countries which import wood for various purposes. For this rainforest to continue to play its dual role of global climate regulator and economic provider, policymakers, loggers, wood professionals and consumers should think of balancing efficiently conservation of forest carbon and production of wooden items. Given the statement of Section 2.3 (Sustainability requirements), we recommend a palliative package organized as follows: an integral and sustainable management of forest resources in the region at all levels of responsibility; a redesign of the criminal codes of riparian countries in order to integrate a deterrent and explicit penalties against any irregular forester; a flexible tax mechanism for legal loggers should be worked out; the creation programs that disclose forestry standards and certification to both operators and consumers of forest products; the strengthening of the community forest management that takes into account the vital needs of the indigenous and tribal people. It is equally recommended that this management should evaluate the quantity, the quality and the collection period for each plant species prized by residents, create reforested areas, develop alternative economies more environment-friendly.

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Appendix A. Supplementary data

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